

Analysis of Earthquake Data from the Greater Los Angeles Basin and Adjacent Offshore Area, Southern California

U.S. Geological Survey Award No. 02HQGR0044

Element I & III

Key words: Geophysics, seismology, seismotectonics

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ABSTRACT

We synthesize and interpret local earthquake data recorded by the Caltech/USGS Southern California Seismographic Network (SCSN/TriNet) in southern California. The goal is to use the existing regional seismic network data to: (1) refine the regional tectonic framework; (2) investigate the nature and configuration of active surficial and concealed faults; (3) determine spatial and temporal characteristics of regional seismicity; (4) determine the 3-D seismic properties of the crust; and (5) delineate potential seismic source zones. Because of the large volume of data and tectonic and geologic complexity of the area, this project is a multi-year effort and has been divided into several tasks.

RESULTS

Comparison of Aftershock Relocations and Velocity Models Through the Vicinities of the 1971 San Fernando and 1994 Northridge Earthquakes, California: Results from Combining LARSE99 Reflection and CISN/SCSN/TriNet Seismicity Data

We use relocated hypocenters and reflection data from LARSE99 to infer the fault surfaces that were ruptured by the 1971 San Fernando and 1994 Northridge earthquakes. Different relocation techniques and different velocity models give somewhat different results. For example, relocation of the San Fernando aftershocks using the technique and velocity model of Mori et al. (1995) gives an alignment of aftershocks at the north end of the aftershock region that projects to the surface at or near the Sierra Madre fault. Relocation of these same aftershocks using the technique and velocity model of Hauksson (2000) moves this alignment not as far south, so that it projects to the surface at or near the San Gabriel fault. Comparison of Mori's and Hauksson's velocity models with that determined independently from LARSE99 indicates that Mori's model is too slow. The relocations of Hauksson are, thus, preferred (Figure 1 and 2).

Mainshock ruptures for the San Fernando earthquake include two echelon planes dipping northward at 45-52 degrees, according to Heaton (1992). There is a hint of these two planes in the relocated aftershocks, but the base of the aftershocks dips northward at a much shallower angle (~25 degrees), passing near the bottoms of both of these inferred planes, and projecting into a prominent north-dipping reflective zone imaged in LARSE99. This reflective zone extends to ~25 km depth at the San Andreas fault. The base of the aftershock zone projects updip to the northwest of the mainshock hypocenter at 25 degrees to the deep projection of the Northridge Hills fault, in the northern San Fernando Valley, as inferred from industry reflection data. Most of these aftershocks to the northwest are along a linear zone that coincides with a lateral ramp in the overlying Santa Susana fault and may, alternatively, reflect a complexity in the San Fernando fault zone. Southeast of the mainshock hypocenter, the base of the aftershocks is steeper than to the northwest.

Mainshock rupture for the Northridge earthquake, as modeled by Wald et al. (1996), was apparently simpler than for the San Fernando earthquake, extending from ~16- to 5-km depth along a plane dipping southward at ~35 degrees. This plane is located at or near the base of the relocated aftershocks and projects downward into a southdipping reflective zone imaged in LARSE99. The dip of the base of the aftershocks, and perhaps also the dip of the main rupture plane, becomes steeper than 35 degrees to the west of the mainshock hypocenter.

Both the San Fernando and Northridge aftershock zones extend about 5 km beyond the updip limits of the modeled mainshock ruptures and interpenetrate one another. Since the modeled rupture plane of Wald et al. (1996) stops at the base of the San Fernando aftershock zone, it might be inferred that the San Fernando rupture truncates the Northridge rupture. However, alignments of Northridge hypocenters are observed above and north of this inferred truncation, suggesting that at least secondary Northridge ruptures penetrate the hanging wall of the San Fernando rupture.

This model construction exercise and uncertainties in the final models point toward some of the challenges of using seismicity and imaging data to constrain the three-dimensional structure of faults at depth. This work is in part appearing in Fuis et al. (2002) and we also have a manuscript in preparation.

The Seismogenic Thickness of the Southern California Crust

The average seismogenic thickness, measured from the surface down to maximum depth of earthquake rupture, for the southern California crust is 15.0 km (+1.2/-1.1 km). We determine the seismogenic thickness using the depth distribution of the seismic moment release of ~19 years of seismicity. We calibrate the depth distribution of moment release from background seismicity by comparing the maximum depth of rupture during moderate to large magnitude earthquakes to the pre-mainshock background seismicity of the respective mainshock region. The calibration shows that the depth above which 99.9% of the moment release of background seismicity occurs, reliably estimates the maximum depth of rupture during moderate to large earthquakes. Locally the seismogenic thickness is highly variable, ranging from less than 10 km in the Salton Trough to greater than 25 km at the southwestern edge of the San Joaquin Valley. Similarly, the seismogenic thickness along the major strike-slip faults can vary significantly along strike, and often does not correspond to the mapped surface segmentation (Figure 3). This manuscript is submitted to BSSA, (Nazareth and Hauksson, 2002).

Seismotectonics of the Coso Range-Indian Wells Valley Region, California: Transtensional Deformation Along the Southeastern Margin of the Sierra Nevada Microplate

Space-based geodetic observations show that the Coso Range and Indian Wells Valley lie along the southeastern margin of the Sierra Nevada-Central Valley (i.e., “Sierran”) microplate, which moves approximately 13-14 mm/yr northwest with respect to stable North America. Detailed analysis of seismicity, including refined hypocenters and kinematic inversions of focal mechanisms, indicates that active crustal extension in Coso Range occurs in a right-lateral transtensional regime along the eastern border of the Sierran microplate. At a regional scale, the seismogenic deformation field in the greater Coso Range-Indian Wells Valley area is a horizontal plane strain characterized by northwest-southeast extension and northeast-southwest shortening; this regime is consistent with distributed dextral shear subparallel to Sierran-North American motion. The Airport Lake fault in northern Indian Wells Valley and the Owens Valley fault are the major strike-slip faults along the eastern margin of the Sierran microplate south and north, respectively, of the Coso Range. Although a Quaternary-active dextral fault (the Little Lake fault) is mapped along the Sierran range front west of the Coso Range, the long-term average slip rate on this structure is an order of magnitude lower than the geodetically determined rate of dextral shear at this latitude. Patterns of Quaternary faulting indicate that the locus of dextral shear instead passes through the Coso Range, which lies in a right-releasing stepover between the Airport Lake and Owens Valley faults. Extension within the stepover region is accommodated in part by opening of Coso Wash as a pull-apart basin. The stepover is bounded on the east by a blind, northwest-striking dextral fault that is well expressed by patterns of microseismicity. Comparison with analogue sandbox models of pull-apart basins suggests that the Coso stepover is a relatively immature structure, consistent with models for an eastward step in the locus of dextral shear along the eastern margin of the Sierran microplate to the Indian Wells Valley and Owens Valley in the past 2-3 Ma. These results are published in Unruh et al. (2002).

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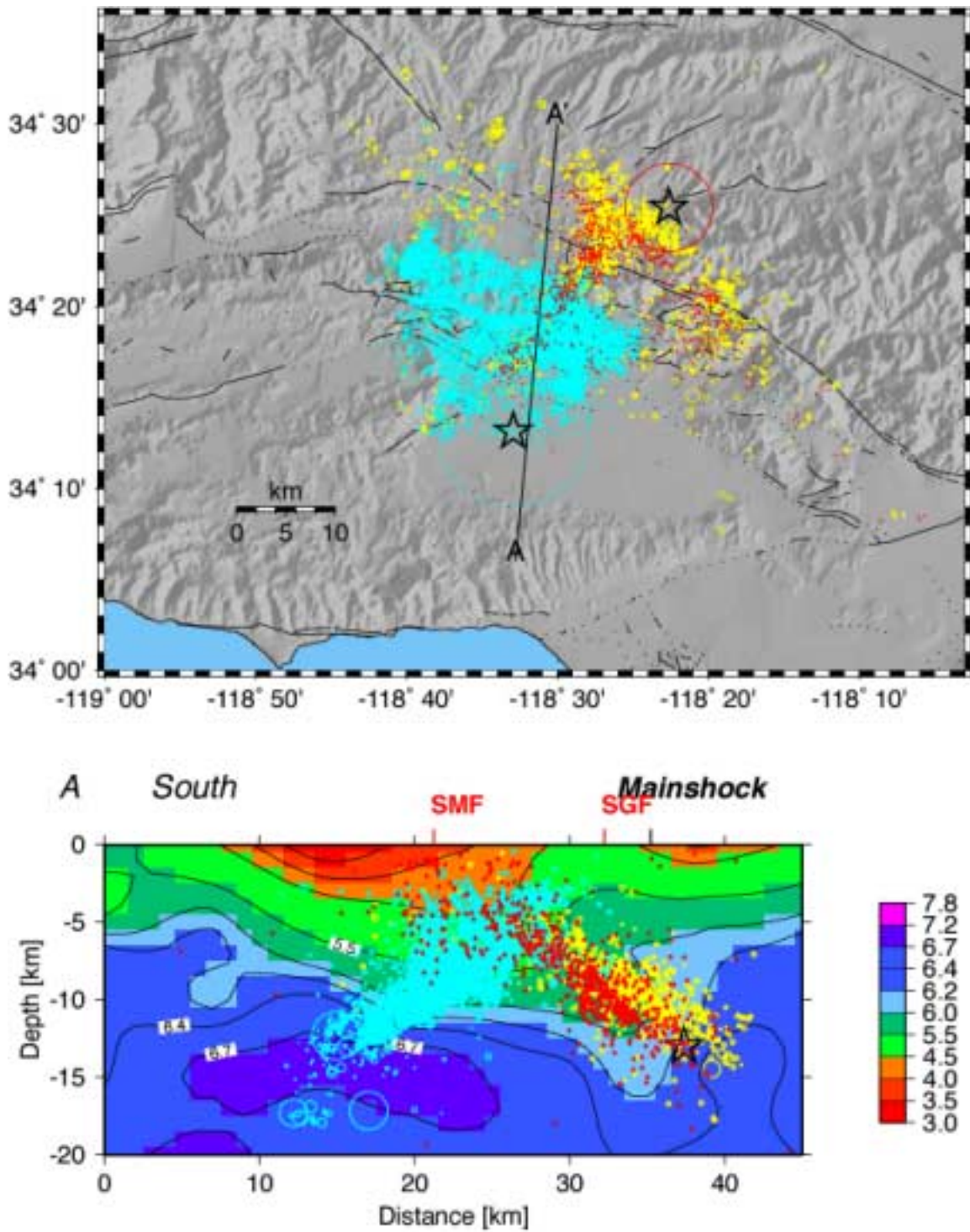


Figure 1. Relocated 1971 San Fernando and 1994 Northridge aftershocks using 3-D 5 km grid velocity model and double difference method of Waldhauser and Ellsworth (2002). Hypocenters shown in red are from Mori et al. (1995).

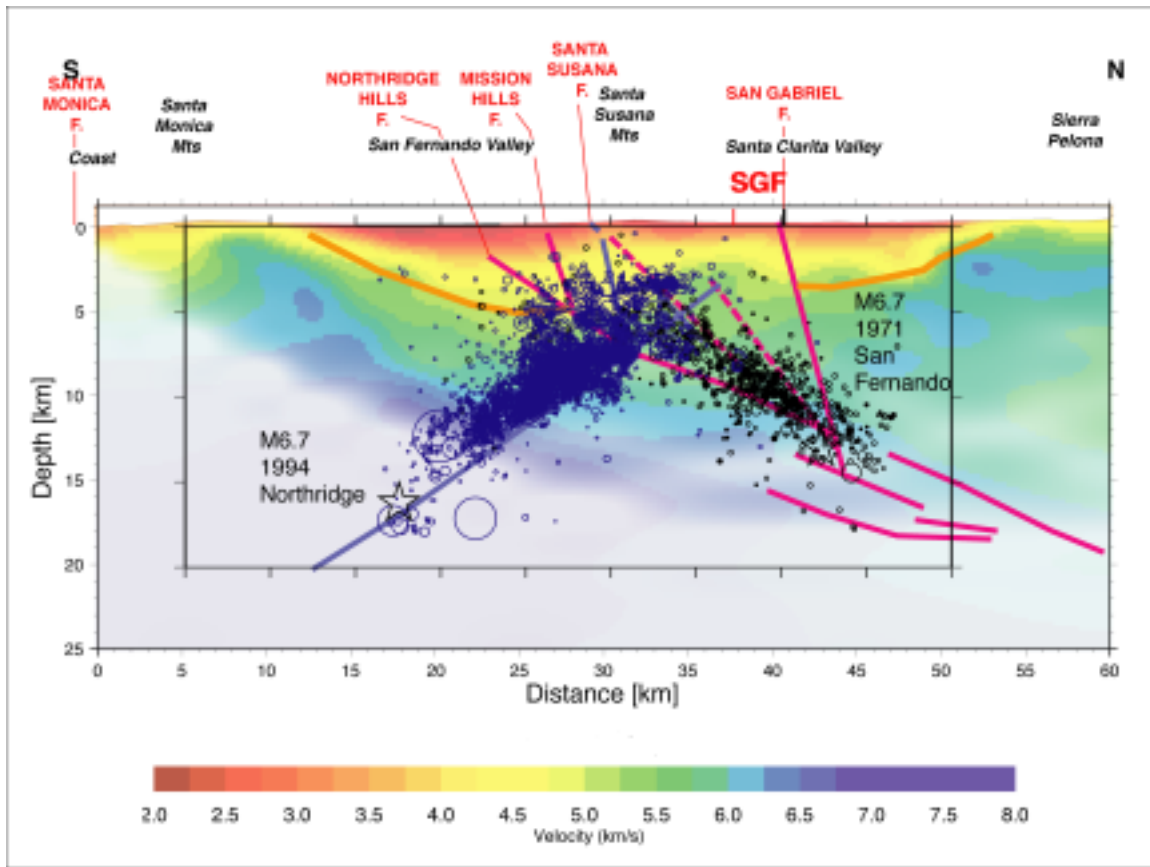


Figure 2. Relocated 1971 San Fernando and 194 Northridge aftershocks as in Figure 1. Background velocity model from Fuis et al. (2002).

Central-Southern San Andreas Fault System

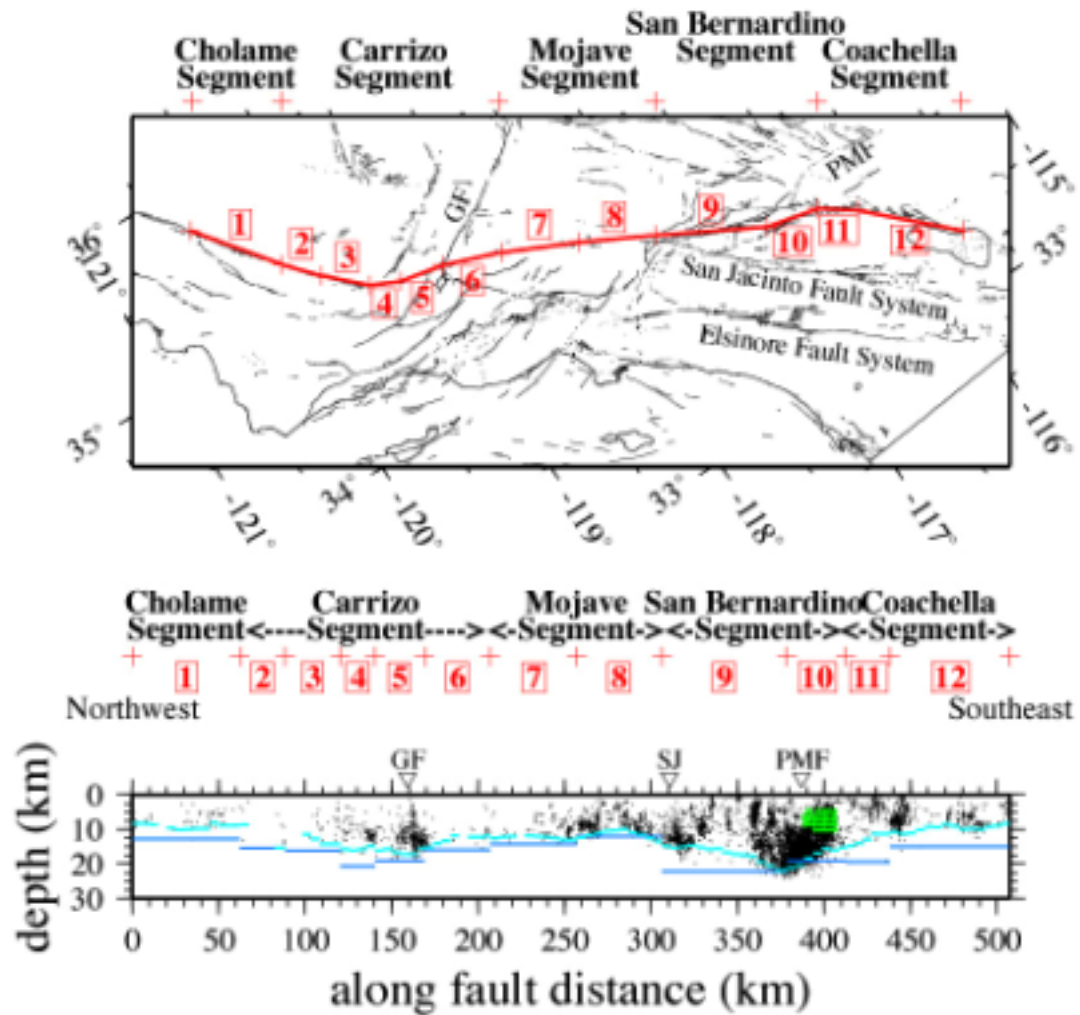


Figure 3. Map and cross section along the San Andreas fault in southern California. Maximum earthquake depths are shown in magenta and blue using different bin lengths.

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NON-TECHNICAL SUMMARY